IS 13736-1 (1993): Classification of environmental conditions, Part 1: Classification of environmental parameters and their severities [LITD 1: Environmental Testing Procedure]

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IS 13736 (Part 1) : 1993
IEC Pub 721-1 : (1990)

भारतीय मानक

पर्यावरण अवस्थाओं का वर्गीकरण

भाग 1 पर्यावरण प्राचल और उनकी गंभीरतायें

Indian Standard

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS

PART 1 CLASSIFICATION OF ENVIRONMENTAL PARAMETERS AND THEIR SEVERITIES

UDC 621·38·038 : 620·193

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

October 1993 Price Group 8

Environmental Testing Procedures Sectional Committee, LT 02

NATIONAL FOREWORD

This Indian Standard, which is identical with IEC Pub 721-1 (1990) 'Classification of environmental conditions — Part 1 : Classification of environmental parameters and their severities', issued by the International Electrotechnical Commission, was adopted by the Bureau of Indian Standards on the recommendation of the Environmental Testing Procedures Sectional Committee (LT 02) and approval of the Electronics and Telecommunication Division Council.

The text of the IEC Standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical with those used in Indian Standards. Attention is particularly drawn to the following:

> Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

The concerned technical committee has reviewed the provisions of IEC 68-2-27 and IEC 79, referred in this standard and has decided that they are acceptable for use in conjunction with this standard.

This Indian Standard deals with classification of environmental parameters and their severities. The subsequent parts are intended to deal with the following:

a) Environmental conditions appearing in nature

b) Classification of groups of environmental parameters and their severities.

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

AMENDMENT NO. 1 SEPTEMBER 1999
TO
IS 13736 (PART 1) : 1993/IEC PUB 721-1 (1990)

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS

PART 1 ENVIRONMENTAL PARAMETERS AND THEIR SEVERITIES

[This Amendment No. 1 is based on Amendment No. 1 to IEC 721-1 (1990). The page numbers mentioned in this Amendment refer to the IEC Page No. given in the standard.]

Page 33

6.3 *Impact from foreign bodies*

Delete in the column "Severity" *the values* 1, 3, 10 *and* 30 *and substitute* 0,2, 0,5, 1, 2, 5, 10 *and* 20.

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 2 SEPTEMBER 1999
TO
IS 13736 (PART 1) : 1993/IEC PUB 721-1 (1990)

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS

PART 1 ENVIRONMENTAL PARAMETERS AND THEIR SEVERITIES

[This Amendment No. 2 is based on Amendment No. 2 to IEC 721-1 (1990). The page numbers mentioned in this Amendment refer to the IEC Page No. given in the standard.]

Page 35

Table 1 (*concluded*)

Delete the existing text of item 7 and replace it by the following new item 7:

Item	Environmental factor Environmental parameter and unit	Severity (see note 1)	Code of conditions (see note 2)				Remarks (Based on IEC 1000-2-5)
			A	W	S	E	
7	**Electric and electromagnetic disturbance**						Radiated disturbance items 7.1 and 7.2. Conducted disturbance items 7.3 to 7.7
7.1	*Magnetic field*						
7.1.1	*Field strength* A/m (harmonics of power systems, frequency range 0,1–3 kHz for *n* = order of harmonics)	0,015 *0,05* 0,15 *0,5* 1 3 10 30 *100* 3/n *10/n* 30/n *100/n*				X	
7.2	*Electric field*						
7.2.1.	*Field strength* V/m kV/m	0,3 1 3 10 30 60 100 140 200 300 600 1 3 *10* 20				X	
7.2.2	*Rate of change of field* (pulsed disturbance) V/(m · ns)	*3* 10 *30* 100 250 *300* 500 1 000 *2 000* 3 000 *10 000*				X	

For notes, see pages 37 to 41 in IEC 721-1 (1990).

Item	Environmental factor Environmental parameter and unit	Severity (see note 1)	Code of conditions (see note 2) A	W	S	E	Remarks
7.3	*Harmonics* Total harmonic distortion factor % of fundamental voltage	8 10			X		
7.4	*Signalling voltage*						
7.4.1	*Amplitude (r.m.s.)* % of U_n	0,6 1,3 5			X		U_n = nominal voltage
	mV	0,6 2					
7.5	*Voltage and frequency variation*						
7.5.1	*Voltage fluctuation* Amplitude % of U_n	3 10			X		U_n = nominal voltage
7.5.2	*Voltage dip/interruption* Dip (10 % to 99 % U_n) Duration s	0,6 3			X		U_n = nominal voltage
	Interruption (100 % of U_n) Duration s	0,6 60			X		
7.5.3	*Voltage unbalance* U_{neg}/U_{pos} %	2 3			X		
7.5.4	*Frequency variation* % of f_n	2			X		f_n = nominal frequency
7.6	*Induced voltage*						
7.6.1	*Amplitude* V	0,05 *0,1* 0,15 *0,3* 0,5 1 3 10 20 *30* 100 300 1 000 3 000			X		

For notes, see pages 37 to 41 in IEC 721-1 (1990).

Item	Environmental factor Environmental parameter and unit		Severity (see note 1)	Code of conditions (see note 2)				Remarks
				A	W	S	E	
7.7	*Transient*							
7.7.1	*Rise time*	ns	0,3 5 10 50 100 500			X		
		µs	1 1,5 10 100					
7.7.2	*Duration*	ns	2 15 50			x		
		µs	5 20 50					
		ms	1 3					
7.7.3	*Amplitude, peak*	kV	0,5 1 1,5 2 4 *6* *8*			x		
7.7.4	*Rate of change of current*	A/ns	10 25 40 *80* *100*			x		

For notes, see pages 37 to 41 in IEC 721-1 (1990).

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Indian Standard

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS

PART 1 CLASSIFICATION OF ENVIRONMENTAL PARAMETERS AND THEIR SEVERITIES

1 Scope

This part of IEC 721 lists environmental parameters and a limited number of their severities within the range of conditions met by electrotechnical products when being transported, stored, installed and used.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of IEC 721. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of IEC 721 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 68-2-27: 1987, Environmental testing. Part 2: Tests – Test Ea and Guidance: Shock.
IEC 79-0: 1983, Electrical apparatus for explosive gas atmospheres – Part 0: General requirements.
IEC 721-2-2: 1988, Classification of environmental conditions – Part 2: Environmental conditions appearing in nature – Precipitation and wind.
IEC 721-3-6: 1987, Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Ship environment.
ISO 2041: 1975, Vibration and shock – Vocabulary.

3 Definitions

For the purposes of this part of IEC 721, the following definitions apply:

3.1 **environmental condition:** Physical, chemical or biological condition, external to a product, to which it is subjected at a certain time.

NOTE – Environmental conditions are generally composed of environmental conditions appearing in nature and environmental conditions generated by the product itself or by external sources.

3.2 **environmental factor:** A physical, chemical or biological influence which, either singly or in combination with other influences, produces an environmental condition (e.g. heat, vibration).

3.3 **environmental parameter:** One or more physical, chemical or biological properties characterizing an environmental factor (e.g. temperature, acceleration).

EXAMPLE – The environmental factor vibration is characterized by the parameters: type of vibration (sinusoidal, random), acceleration and frequency.

3.4 **severity of environmental parameter:** A value of each quantity, characterizing the environmental parameter.

EXAMPLE – The severity of sinusoidal vibration is defined by values of the acceleration (in m/s^2) and frequency (in Hz).

3.5 **application, product application:** A condition or a situation met by a product.

EXAMPLES of applications – Office working rooms, steelworks, ground transport. Applications *do not refer* to a class of products (e.g. computers).

3.6 **group of environmental parameters and their severities:** A set of environmental conditions characteristic for a specific use or purpose.

4 Environmental factors and parameters

4.1 *General*

The actual environmental conditions to which a product is exposed are normally complex and composed of a number of environmental factors and corresponding parameters. When defining the environmental conditions for a certain product application, it is therefore necessary to:

- list the environmental factors involved;
- select appropriate severities for each parameter.

The environmental influences on a product in a certain application is a result of:

- conditions of the surrounding medium, normally air or water (in certain cases, soil);
- conditions of the structure to which the product is connected;
- influences from external sources or activities.

When selecting environmental factors and parameters for a certain product application it is therefore necessary to check these conditions and influences for single, combined and sequential environmental factors as they occur.

The terms for the environmental factors and parameters correspond in general to those used in IEC 68, as far as applicable.

4.2 *List of single environmental factors and parameters and their severities.*

The list of environmental factors and parameters given in table 1 shall be used:

- as a check list to ensure that relevant factors and parameters have been considered;
- to achieve uniformity in the description of the environment.

The severities given in connection with each parameter in table 1 shall be used for standardization purposes. These are restricted to the severities of the environmental conditions to which a product may be exposed.

It is not intended to cover the severities of the resulting stresses on the product. For example, the severities are intended to cover the temperatures of surrounding media (e.g. air, water, soil, water vapour, ice, oil, etc.) and the temperatures of the structure to which the product is connected, but are not intended to cover the temperatures of hot points on the product itself.

The severities are primarily related to limit environmental conditions, and do not include conditions for reference measurements, calibration, etc.

4.3 *Combined environmental factors*

A product is exposed simultaneously to a number of environmental factors and corresponding parameters. The effect of a combination of environmental factors is especially important when exposure to a combined environment affects the product differently from exposure to a sequence of environmental factors.

When selecting environmental factors for a certain product application it is therefore recommended to check the environmental factors, the combination of which may need to be taken into account.

4.4 *Sequences of environmental factors*

Certain effects of exposing a product to environmental conditions are a direct result of exposing it to two or more factors or parameters in a direct sequence. Two important examples are:

- thermal shock,
  which may be the result of exposing the product to high temperature conditions immediately after it has been exposed to low temperature conditions or vice versa, or by subjecting the product to water (rain, water jets, sea waves, immersion) directly after being exposed to high temperature conditions;
- formation of ice,
  which may be the result of exposing the product to conditions of temperatures below freezing point immediately before or after it has been exposed to humidity, rain or water from sources other than rain.

It is recommended that these possibilities be taken into account when defining the environmental conditions to which a certain product will be exposed.

Table 1*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2) A	W	S	E	Remarks
1 **Climatic conditions**							
1.1 *Cold and heat*							
1.1.1	Temperature, °C	*−80* −65 −55 −50+ −40 −33+ −25 −20 −15 −5 Freezing point of water +5 +10 +15 +20 +25 +30 +35+ +40 +45 +50 +55 +60 +70 +85 *+100* *+125* *+155* *+200*	x	x	x		+ Severity derived from climatograms relevant to specific open-air types of climate This severity refers only to water, not to air or structures (see IEC 721-3-6)
1.1.2	Rate of change of temperature, K/min Rate of change of temperature, K/s	0,1 0,5 1 3 5 10 *1* 5	x	x	x		As mentioned in 4.4, a product can be subjected to temperature shocks when it is moved from one medium to another (e.g. from outdoors to indoors) or when it is subjected to a medium of a temperature other than the temperature of the product (e.g. when subjected to rain, water jets). The parameters defining the severity of the temperature shock shall then be chosen from the list of temperatures (air temperature, water temperature), either as a single environmental parameter or combined with movement of the surrounding medium

* For notes, see pages 37 to 41.

Table 1* *(continued)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2) A	W	S	E	Remarks
1.2 *Humidity*							
1.2.1	Relative humidity, %	4 5 10 15 20 *50* 75 85 95 100	x				The effect of humidity on a product is always the effect of a combination of relative humidity with other environmental parameters, primarily temperature and change of temperature
1.2.2	Absolute humidity, g/m^3 (water content)	0,003 0,02 0,03 0,1 0,26 0,5 0,9 1 2 4 15 22 25 29 35 36 48 60 62 78 80	x				The severities are derived from climatograms relevant to specific open-air types of climate
1.3 *Pressure*							
1.3.1	Air pressure, kPa	*20* 30 *53* 70 *84* 106 *130*	x				
1.3.2	Water pressure, kPa	*200* *500* *1000* *5000* *30000*		x			
1.3.3	Rate of change of pressure, kPa/s	0,1 *1*	x	x			

* For notes, see pages 37 to 41.

Table 1* *(continued)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2) A	W	S	E	Remarks
1.4 *Movement of surrounding medium, including movement of the product relative to the surrounding medium*							
1.4.1	Velocity, m/s	0,5 1 5 10 20 30 50	x	x			
1.5 *Precipitation*							
1.5.1	*Rain* Intensity, mm/min	*0,3* *1* *2* *3* 6 15				x	The intensity shall be taken as the amount of water hitting a horizontal surface per time unit. This may be considerably less than the amount of water hitting a surface perpendicular to the direction of the rain
1.5.2	*Snow, drifting* Intensity, kg/(m²·s)	*0,3* *1* *3*				x	The severity 3 kg/(m²·s) applies only to conditions near to the ground. See IEC 721-2-2 For loads caused by snow or ice, see the factor *"Static load"*, item 6.7
1.5.3	*Hail* Impact energy, J	*1* *40* *150*				x	For hailstone diameter, see IEC 721-2-2
1.6 *Radiation*							
1.6.1	*Solar radiation* Intensity, W/m²	*300* 500 700 *1000* 1120				x	Only the heating effect of solar radiation is considered here. Radiation of wavelengths such as in the ultra-violet range can affect some products in other ways
1.6.2	*Heat radiation* Intensity, W/m²	600 1200				x	Except from sun
1.6.3	*Ionizing radiation* Intensity					x	No severities at present

* For notes, see pages 37 to 41.

Table 1* *(continued)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2) A	W	S	E	Remarks
1.7 *Water from sources other than rain*							
1.7.1	*Dripping water* Intensity					x	No severities at present
1.7.2	*Splashing, spraying water, water jets and waves* Water velocity, m/s	0,3 1 3 10 *30*				x	
1.7.3	*Immersion or submersion* Water depth, m			x			No severities at present
1.8	*Wetness*				x		Wetness of walls and other surfaces. No parameter or severities at present
1.9	*Condensation*		x			x	No parameter or severities at present
1.10	*Formation of ice and frost*						
1.10.1	Intensity, mm/h	*3* *10* *30*	x			x	
2 Biological conditions							
2.1	*Flora*		x	x			Presence of mould, fungus, etc. No parameter or severities at present
2.2	*Fauna*		x	x			Presence of rodents or other animals, excluding or including termites No parameter or severities at present
3 Chemically active substances (see note 3)							For explosive gases and vapours, see IEC 79-0
3.1	*Sea salt* Concentration, g/m³	*0,3* *1*	x				
	kg/m³	30 40		x			

* For notes, see pages 37 to 41.

Table 1* *(continued)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2)				Remarks
			A	W	S	E	
3.2	*Road salt* Concentration, g/m³ kg/m³		x	x			No severities at present
3.3	*Sulphur dioxide* Concentration, mg/m³	0,01 *0,03* 0,1 0,3 1 *3* 5 10 13 *30* 40 *100* *300*	x				
3.4	*Hydrogen sulphide* Concentration, mg/m³	0,0015 *0,003* 0,01 *0,03* 0,1 *0,3* 0,5 *1* 3 10 14 *30* 70 *100*	x				
3.5	*Nitrogen oxides* Concentration, mg/m³	*0,01* *0,03* 0,1 *0,3* 0,5 1 3 9 10 20 *30* *100*	x				Expressed in the equivalent values of nitrogen dioxide

* For notes, see pages 37 to 41.

Table 1* *(continued)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2)				Remarks
			A	W	S	E	
3.6	*Ozone* Concentration, mg/m³	0,004 0,01 *0,03* 0,05 0,1 0,2 0,3 1 2 *3* *10* *30*	x				
3.7	*Ammonia* Concentration, mg/m³	0,3 1 3 10 35 175	x				
3.8	*Chlorine* Concentration, mg/m³	0,001 0,01 0,1 0,3 0,6 1 3	x				
3.9	*Hydrogen chloride* Concentration, mg/m³	0,001 0,01 0,1 0,5 1 5	x				
3.10	*Hydrogen fluoride* Concentration, mg/m³	0,001 0,003 0,01 0,03 0,1 2	x				
3.11	*Organic hydrocarbons* Concentration, mg/m³		x				No severities at present

* For notes, see pages 37 to 41.

Table 1* *(continued)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2) A	W	S	E	Remarks
4 Mechanically active substances							
4.1	*Sand (including grit)* Mass per volume unit, g/m³	*0,01* 0,03 0,1 0,3 1 3 4 10	x				In addition to the mass per volume unit, the distribution of particle sizes is of importance. For the completion of the list with regard to this, no parameter or severities at present
4.2	*Dust*		x				Covers different types of dust. No requirement at present for their classification In some cases organic dust (e.g. textile fibres) may burn when deposited on heat dissipating products. The combustion products may then be of importance
4.2.1	*Dust suspension* Mass per volume unit, mg/m³	0,01 0,2 0,4 4 5 15 20	x				
4.2.2	*Dust sediment* Rate of sedimentation, mg/(m²·h)	0,4 1 1,5 3 *10* 15 20 *30* 40 80	x				
4.3	*Slurry* Concentration, kg/m³			x			No severities at present
4.4	*Soot* Rate of sedimentation		x				No severities at present

* For notes, see pages 37 to 41.

Table 1* *(continued)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2) A	W	S	E	Remarks
5 Contaminating fluids							
5.1	*Motor oil*					x	No parameter or severities at present
5.2	*Gearbox oil*					x	This list is not exhaustive. The fluids listed
5.3	*Hydraulic oil*					x	under items 5.1 to 5.9 may have differing
5.4	*Transformer oil*					x	characteristics
5.5	*Brake fluid*					x	
5.6	*Cooling fluid*					x	
5.7	*Grease*					x	
5.8	*Fuel*					x	
5.9	*Battery electrolyte*					x	
6 Mechanical conditions							
6.1 *Vibration*							
6.1.1	*Stationary vibration, sinusoidal* Spectrum type A: peak displacement $\hat{s}$, mm peak acceleration $\hat{a}$, m/s² $f_c \approx 9$ Hz 2 Hz < f < 200 Hz	$\hat{s}$ / $\hat{a}$ 0,3 / 1 *0,7* / *2* 1,5 / 5 3,5 / 10 7,5 / 20 10 / 30 15 / 50			x	x	"Spectrum" in item 6.1.1, see note 4 and figure 1 Cross-over frequency f_c is the frequency where the spectrum changes from constant displacement amplitude to constant peak acceleration or to a different value of peak acceleration
	Spectrum type B: peak displacement $\hat{s}$, mm peak acceleration $\hat{a}$, m/s² $f_c \approx 60$ Hz 10 Hz < f < 500 Hz	$\hat{s}$ / $\hat{a}$ *0,15* / *20* *0,35* / *50* *0,75* / *100* *1* / *150*					
	Spectrum type C: peak displacement $\hat{s}$, mm peak acceleration $\hat{a}_1$, m/s² peak acceleration $\hat{a}_2$, m/s² $f_{c1} \approx 9$ Hz, $f_{c2} \approx 200$ Hz 2 Hz < f < 500 Hz	$\hat{s}$ / $\hat{a}_1$ / $\hat{a}_2$ 3,3 / 10 / 15 7,5 / 20 / 40					
	Spectrum type D: peak displacement 1,5 mm peak acceleration $\hat{a}$, m/s² cross-over frequency f_c, Hz 2 Hz < f < 200 Hz	/ $\hat{a}$ / f_c D_1 / 10 / 13 D_2 / 20 / 18 D_3 / 50 / 28					

* For notes, see pages 37 to 41.

Table 1* *(continued)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2) A	W	S	E	Remarks
6.1.2	*Stationary vibration, random* Spectrum type G: ASD_1 below 200 Hz $(m/s^2)^2/Hz$ ASD_2 above 200 Hz $(m/s^2)^2/Hz$ 2 Hz < *f* < 2000 Hz	ASD_1 ASD_2 0,3 0,1 1 0,3 3 1 *10* *3* *30* *10*			x	x	ASD: Acceleration Spectral Density. "Spectrum" in item 6.1.2, see note 5 and figure 2
	Spectrum type H: ASD $(m/s^2)^2/Hz$ 20 Hz < *f* < 2000 Hz	ASD *0,3* *1* *3* *10* *30*					
6.1.3	*Non-stationary vibration, including shock* Spectrum type L: peak acceleration $\hat{a}$, m/s^2	40 70			x	x	"Spectrum" in item 6.1.3 is shock response spectrum, see note 6 and figure 3
	Spectrum type I: peak acceleration $\hat{a}$, m/s^2	50 100 *150* 300 *500* *1000*					
	Spectrum type II: peak acceleration $\hat{a}$, m/s^2	100 250 300 1000					
	Spectrum type III: peak acceleration $\hat{a}$, m/s^2	500 *1500* *3000* *5000* *10000*					

* For notes, see pages 37 to 41.

Table 1* *(continued)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2) A	W	S	E	Remarks
6.2	*Free fall* Drop height, m	0,025 0,05 0,1 0,25 0,5 1 1,2 1,5 *2,5* *5* *10*				x	The effect of a free fall also depends on the type of surface on to which the product falls The severities are mass-dependent
6.3	*Impact from foreign bodies* Impact energy, J	*1* *3* *10* *30*				x	
6.4	*Angular motion, dynamic* Angle/frequency, ± °/Hz	4/0,05 *5/0,167* *10/0,167* 10/0,2 22,5/0,14 *25/0,167* 35/0,125 *45/0,167*			x		Rolling, pitching and yawing
6.5	*Angular deviation, static* Angle, °	10 15			x		List and trim
6.6	*Steady state acceleration* Acceleration, m/s^2	5 6 10 20 *50* *100* *200* *500* *1000*			x		

* For notes, see pages 37 to 41.

Table 1* *(concluded)*

Item No.	*Environmental factor* Environmental parameter and unit	Severity (see note 1)	Code of condition (see note 2) A	W	S	E	Remarks
6.7	*Static load* Load pressure, kPa	*0,1* *0,3* *1* *3* 5 10 *30* *100*				x	
6.8	*Toppling*					x	No parameter or severities at present
7 **Electromagnetic disturbance**					x	x	No factors, parameters or severities at present

* For notes, see pages 37 to 41.

NOTES relating to table 1

1 Severities in italics are not applied in IEC 721-3.

2 A – Conditions of surrounding medium, air;
W – Conditions of surrounding medium, water;
S – Conditions of the structure to which the product is connected;
E – Conditions due to influences from external sources.

3 Concentration of substances in air is given in milligrams per cubic metre. The use of values in parts per million (ppm) is deprecated.

4. *Stationary vibration, sinusoidal*
Vibration is characterized by an oscillatory movement (displacement, velocity or acceleration is given as a function of time). Periodic vibration can also be characterized by a line spectrum giving the amplitude of each frequency component. The classification given here is based on the generalization that each frequency component may occur arbitrarily within a certain frequency range.

Most commonly very small accelerations occur in the low-frequency range, whilst displacements may be rather large. In the high-frequency range, larger accelerations occur whilst displacements are rather small. Model spectra with constant displacements in the low-frequency range and constant accelerations in the high-frequency range are used. The cross-over frequencies have been selected, as shown in figure 1, so that the model spectra A and C take into account cases where the vibration is dominated by low-frequency components, and the model spectra B and D cover cases where the medium and high-frequency components dominate.

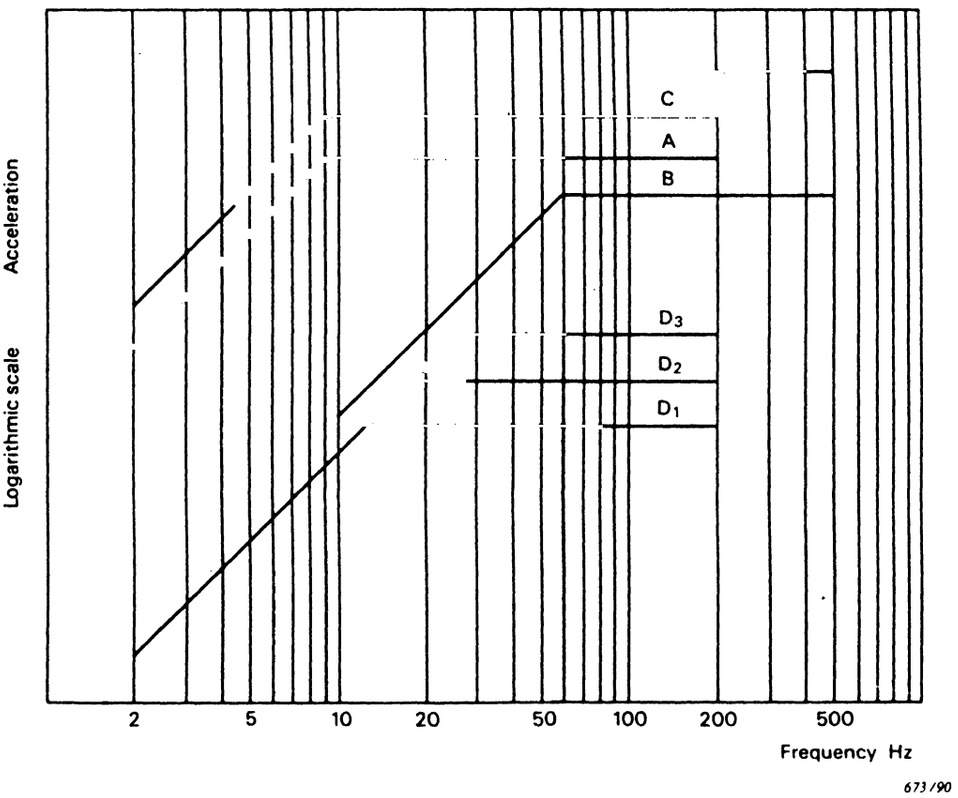

Figure 1 – Model spectra for sinusoidal vibration

5 *Stationary vibration, random*

Non-periodic (random) vibration can be characterized by a continuous frequency spectrum. In random vibration it is not possible to define an acceleration amplitude as a function of frequency. It is instead characterized by the amount of energy within each frequency band. In order to arrive at a quantity which is independent of the bandwidth, acceleration spectral density (ASD) is given as a function of frequency, defined as:

$$S(f) = \lim_{\Delta f \to 0} \frac{a^2_{\text{rms}, \Delta f}}{\Delta f}$$

where $a_{\text{rms}, \Delta f}$ *is the root mean square value of the acceleration within the frequency range* Δf.

Two model spectra given in terms of acceleration spectral density as a function of frequency are used, one with a more pronounced low-frequency content, the other with a more evenly distributed vibration energy, as shown in figure 2.

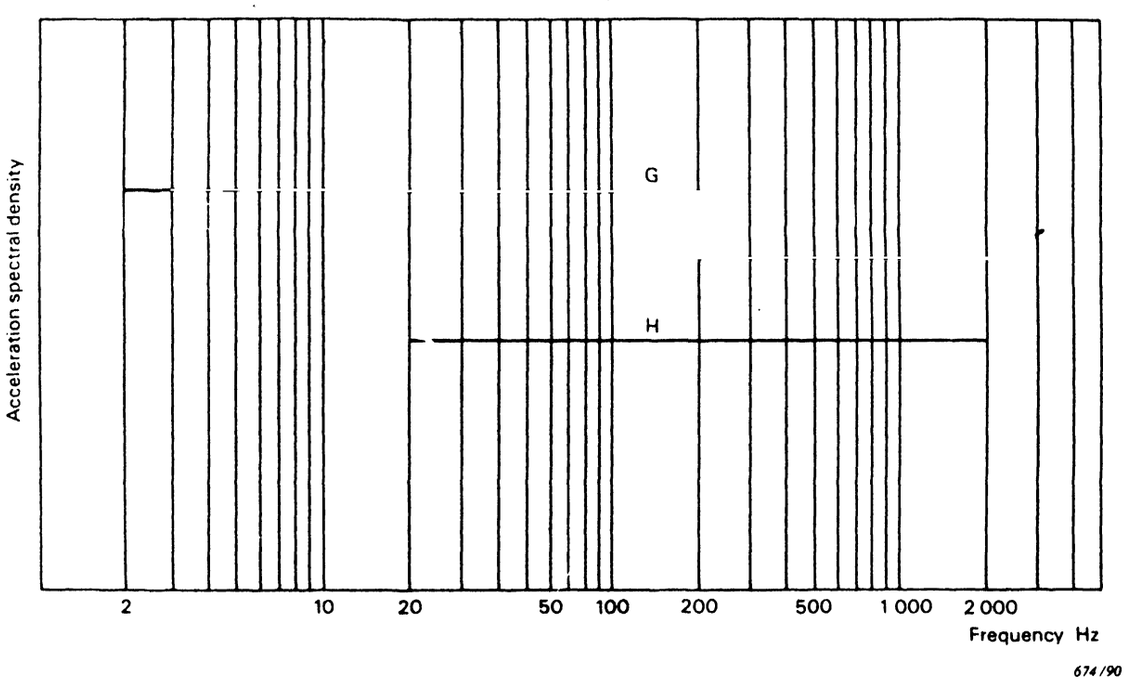

Figure 2 – Model spectra for random vibration

6 *Non-stationary vibration, including shock*

For non-stationary vibration including shock the most convenient way of presentation is by using the first order undamped maximax shock response spectrum.

The concept of shock response spectrum (shock spectrum) is described in detail in Appendix B of IEC 68-2-27. Reference regarding definitions of non-stationary vibration and of shock is also made to ISO 2041.

Four model spectra are used as shown in figure 3:

L = One typical spectrum for shocks with long duration and low peak acceleration.

I = One typical spectrum for shocks with long duration and relatively low peak acceleration.

II = One typical spectrum for shocks with medium duration and medium peak acceleration.

III = One typical spectrum for shocks with short duration and high peak acceleration.

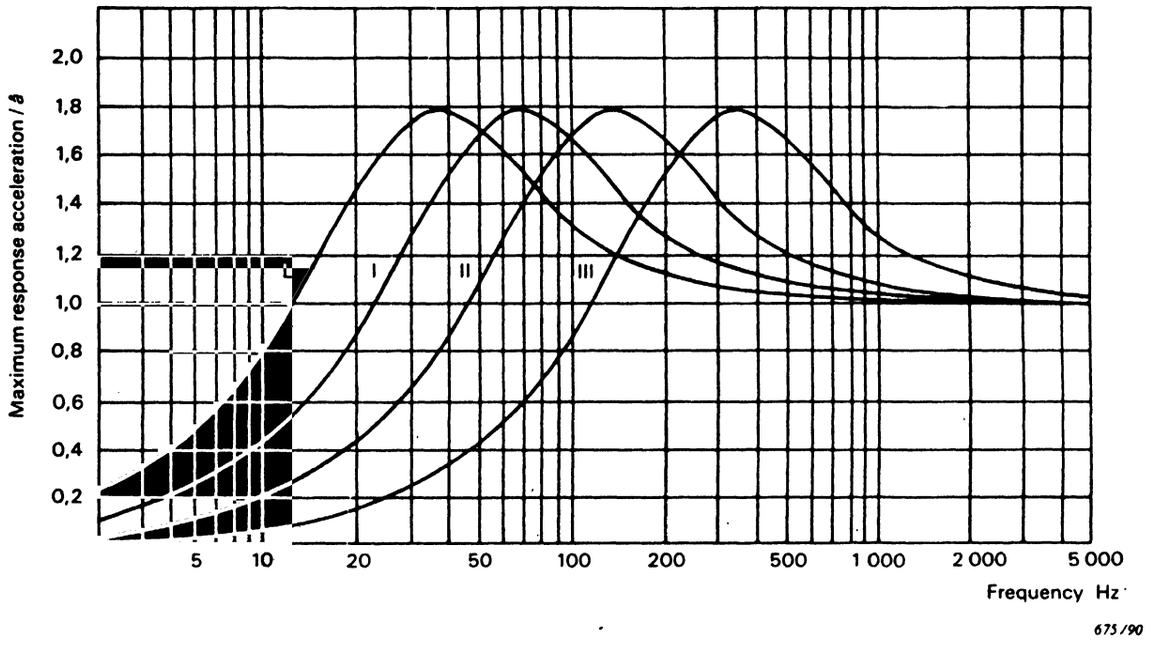

Figure 3 – Model shock response spectra
(first order maximax shock response spectra)

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